

Development of a supportive-educative health education intervention for family caregivers of diabetes mellitus patients: a quasi-experimental study

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ABSTRACT

Despite growing evidence on family involvement in diabetes management, few studies have developed and tested structured educational programs targeting family caregivers as active companions in resource-limited settings. This study aimed to evaluate the effectiveness of a comprehensive family support education program based on the five pillars of diabetes mellitus (DM) management in enhancing family knowledge and educational support capacity. A quasi-experimental design with non-probability sampling was employed, involving 157 respondents (intervention group: 72; control group: 85). Social support was measured using a modified Diabetes Social Support Questionnaire-Family. Data were analyzed using independent and paired t-tests. The intervention group demonstrated a significant increase in mean educational support scores from 61.81 to 90.85 (mean difference = 29.04; $p < 0.001$; Cohen's $d = 1.82$), indicating a large effect size. The control group showed negligible changes. Poor knowledge decreased from 45.8% to 26.39% in the intervention group, while intermediate knowledge increased substantially. The structured family education program produced a large and statistically significant improvement in caregiving capacity. These findings underscore the need for public health policies to integrate family-centered educational interventions into routine diabetes care, particularly in settings with limited healthcare infrastructure, to reduce disease burden and improve patient outcomes.

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1. INTRODUCTION

Diabetes mellitus (DM) is a significant public health issue worldwide, impacting not only patients but also their family caregivers, who often shoulder considerable responsibility in managing the disease. The involvement of family members in diabetes management is especially critical due to the chronic and complex nature of the illness, which frequently requires ongoing monitoring, dietary management, and education related to glucose control and overall health maintenance. Family caregivers play a crucial role in enhancing the quality of life for diabetes patients, particularly for older adults or individuals with comorbid cognitive impairments, as they are integral members of the healthcare team [1]-[3].

Caregivers face a steep learning curve to acquire essential skills and knowledge necessary for effective diabetes management, including medication management and dietary control. Structured

educational interventions for family caregivers have been shown to significantly improve their knowledge and self-efficacy, leading to better health outcomes for diabetes patients [4]-[6]. This educational support is essential, as many caregivers report inadequate training and insufficient support systems, which can lead to caregiver burnout and negatively impact patient care [7], [8].

From a public health systems perspective, diabetes mellitus represents a substantial global burden, with prevalence projected to reach 10.2% by 2030, disproportionately affecting low- and middle-income countries (LMICs) [9]. Epidemiological data reveal that rural populations face compounded disadvantages due to poor healthcare infrastructure, workforce shortages, and limited access to specialized diabetes services [10], [11]. In West Africa, frontline primary healthcare workers frequently lack training in evidence-based diabetes management standards [12], while in South Asia, healthcare initiatives remain unevenly implemented, particularly in rural areas [13]. A multinational consensus emphasized that LMICs struggle with insufficient clinical staff, inadequate laboratory facilities, and restricted access to diabetes resources [14].

The challenges faced by family caregivers are amplified in regions lacking robust healthcare systems. In rural areas, these difficulties can increase due to limited access to formal health education and support resources, underscoring the necessity for educational programs tailored to the specific needs of these populations [15], [16]. It is vital to design interventions that consider the economic and social contexts of caregiving, ensuring guidelines are culturally relevant and accessible to various demographic groups, particularly in low- and middle-income settings [17].

Recognizing the vital role of family caregivers in diabetes management highlights the need for targeted supportive and educational interventions. These programs should focus not only on clinical knowledge but also on mental health support and resilience-building for caregivers, enabling them to manage caregiving demands while maintaining their well-being [8], [18], [19]. As the health of caregivers improves, the quality of care they provide also improves, creating a positive feedback loop that benefits patient outcomes [4].

A critical gap remains in the development of comprehensive, family-unit-level educational programs designed for resource-limited contexts, where formal healthcare support is scarce and families collectively assume caregiving responsibilities. Our study advances existing knowledge by shifting the unit of intervention from individual caregivers to the entire family system, recognizing that diabetes management in practice involves distributed responsibilities among multiple household members. Furthermore, unlike prior studies that predominantly assessed knowledge acquisition alone, our program integrates clinical education with psychosocial support and resilience-building components within a culturally adapted framework. This holistic, systems-oriented approach addresses the interconnected needs of caregiving families rather than isolated individuals, representing a methodological and conceptual advancement in family-based chronic disease interventions. We have revised the introduction to explicitly articulate this gap and the study's distinct contribution to public health science.

2. METHOD

2.1. Design

This study employed a quasi-experimental design with a non-equivalent control group, a pre-test and post-test approach. This design was selected as it permits comparison between intervention and control groups in community-based settings where true randomization is neither feasible nor ethical due to practical constraints related to geographic clustering of participants within the Simbarwaringin Community Health Center catchment area.

The intervention group received a structured family support education program centered on the five pillars of DM management: i) diabetes education, ii) medical nutrition therapy, iii) physical exercise, iv) pharmacological therapy, and v) self-monitoring of blood glucose (SMBG). The control group received standard care without additional educational intervention or family support programming.

The intervention was implemented over three months (February–April 2025), with sessions scheduled twice weekly, each lasting approximately 1–2 hours. The intervention comprised three sequential phases. In Phase 1 (weeks 1–3), structured didactic sessions were delivered covering each of the five pillars through interactive presentations, visual aids, and printed educational materials. In Phase 2 (weeks 4–8), supportive family groups were formally established, consisting of 8–10 family members per group, facilitated by trained health educators. These sessions employed group discussions, role-playing, and case-based problem-solving to reinforce knowledge application. In Phase 3 (weeks 9–12), intensive mentoring was provided to family caregivers, focusing on practical skill-building, including meal planning, medication administration support, blood glucose monitoring techniques, and motivational strategies for encouraging patient adherence to physical activity regimens. Throughout all phases, continuous monitoring and

formative evaluation were conducted by research assistants using structured observation checklists to assess fidelity of intervention delivery and participant engagement.

It is important to acknowledge that the absence of randomization constitutes a significant methodological limitation, as it introduces the possibility of selection bias and confounding variables that may influence group comparability at baseline. To partially mitigate this concern, baseline demographic and clinical characteristics were compared between groups using chi-square tests for categorical variables and independent t-tests for continuous variables, enabling identification of any pre-existing differences that could confound the results. Furthermore, the use of non-probability sampling and the naturalistic community setting limits the extent to which causal inferences can be drawn, and findings should be interpreted with appropriate caution regarding internal validity.

2.2. Setting and population

This research was conducted from February to June 2025 in the working area of the Simbarwaringin Community Health Center (*Puskesmas*), Central Lampung, Indonesia. The target population comprised all families of patients diagnosed with diabetes mellitus. A total of 365 individuals were registered at the health center and included in the population.

2.3. Sampling technique

A non-probability purposive sampling technique was employed. Purposive sampling was deliberately selected because the study required participants who met specific eligibility criteria that could not be satisfied through random selection from the general population. Specifically, participants were required to have a family member with a confirmed DM diagnosis and the ability to communicate verbally in Indonesian, necessitating a criterion-based selection process.

The authors acknowledge that non-probability sampling introduces inherent limitations, including potential selection bias and reduced generalizability of findings to the broader population of DM patient families. The purposive approach may have resulted in a sample that is systematically different from the target population in unmeasured characteristics, such as motivation, health literacy, or pre-existing engagement with health services. These limitations should be considered when interpreting the study findings.

2.4. Sample size determination

The minimum required sample size was calculated using the Slovin formula, where $N = 365$ (total population) and $e = 0.05$ (margin of error), yielding a minimum required sample of approximately 191 respondents. However, after applying inclusion and exclusion criteria, 157 eligible respondents were obtained, representing 82.2% of the calculated minimum. This shortfall is acknowledged as a limitation that may reduce statistical power and increase the risk of Type II error. The 157 respondents were allocated into an intervention group ($n = 72$) and a control group ($n = 85$). Group allocation was based on geographic proximity to the health center and willingness to attend scheduled intervention sessions, rather than through randomization, which further underscores the potential for selection bias.

2.5. Inclusion and exclusion criteria

Inclusion criteria were: i) willingness to participate as a respondent, confirmed through written informed consent; ii) ability to communicate verbally in Indonesian; and iii) having a family member currently diagnosed with diabetes mellitus and actively receiving treatment at the Simbarwaringin Community Health Center.

Exclusion criteria were: i) unwillingness to participate in the study; ii) inability to communicate verbally in Indonesian, which would impede comprehension and interaction during educational sessions and data collection; iii) families whose members were not currently receiving treatment or not officially diagnosed with DM at the time of the study; and iv) respondents with comorbid health conditions that could independently affect the dependent variables under investigation.

2.6. Variables

The independent variables in this study were six domains of family supportive behavior: i) nutritional regulation support, ii) physical exercise support, iii) pharmacological therapy support, iv) stress management support, v) self-blood glucose testing support, and vi) educational support. The dependent variable was knowledge regarding diabetes mellitus management. Demographic variables, including age, sex, education level, duration of caregiving, and relationship to the DM patient, were collected as potential covariates.

2.7. Measurement tool

Data were collected using a modified version of the Diabetes Social Support Questionnaire-Family (DSSQ-Family), originally developed to evaluate social support received by families of diabetes patients. Modifications were made to ensure contextual appropriateness for the Indonesian community setting and relevance to the six independent variable domains examined in this study. The modified instrument consisted of items rated on a Likert-type scale, with higher scores indicating greater levels of family support.

2.8. Validity and reliability testing

Prior to data collection, the modified DSSQ-Family underwent rigorous psychometric evaluation. Content validity was established through expert judgment by a panel of three specialists in nursing and endocrinology, who assessed item relevance, clarity, and representativeness of the constructs measured. Items were revised based on expert feedback until consensus was achieved.

Construct validity was evaluated through a pilot test, with item-total correlations calculated using Pearson's product-moment correlation coefficient. Items were retained only if the calculated *r*-value exceeded the critical *r*-table value at the 0.05 significance level, ensuring that each item significantly contributed to the overall construct being measured. Internal consistency reliability was assessed using Cronbach's alpha coefficient, yielding a value of 0.73. These procedures confirmed that the instrument was psychometrically adequate for use with the study population.

2.9. Outcome measurement

At the conclusion of the intervention period, the independence of DM patients was assessed based on several behavioral indicators. These indicators included adherence to a healthy diet, engagement in regular physical activity, safe and appropriate use of diabetes medication, and consistent self-monitoring of blood glucose. They were designed to capture changes in adaptive behaviors with the potential to improve quality of life and reduce diabetes-related complications.

2.10. Data analysis

Data analysis was conducted in sequential stages. First, all collected data were cleaned, coded, and screened for missing or invalid responses. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were computed to characterize the demographic profile and baseline attributes of respondents in both groups. Baseline equivalence between the intervention and control groups was assessed using chi-square tests for categorical variables and independent-samples *t*-tests for continuous variables. This step was critical given the non-randomized design, as it enabled identification of pre-existing group differences that could serve as confounders.

Normality of data distribution was assessed using the Shapiro-Wilk test before parametric testing. The paired-sample *t*-test was employed to evaluate within-group changes (pre-test to post-test) in the intervention group, thereby determining whether statistically significant improvements occurred following the educational program. The independent two-sample *t*-test was applied to compare post-intervention outcomes between the intervention and control groups, assessing whether significant between-group differences existed in knowledge and adaptive behavior scores. A significance level of $\alpha = 0.05$ was adopted for all statistical tests. Effect sizes (Cohen's *d*) were calculated to supplement significance testing and provide a measure of practical significance (Cohen, 1988). All analyses were performed using SPSS version 25.0. It should be noted that the analytical approach does not include adjustment for potential confounders through multivariate techniques such as analysis of covariance (ANCOVA), which represents a limitation given the non-randomized design. Future studies should consider incorporating covariate adjustment to strengthen causal inference.

3. RESULTS AND DISCUSSION

Table 1 reveals that both groups were predominantly productive-age and female, with slightly higher proportions in the intervention group (91.67% productive; 81.94% female). The intervention group had more participants diagnosed with DM for ≥ 1 year (40.3% vs. 18.82%). Notably, post-intervention blood glucose levels below 200 mg/dL were substantially higher in the intervention group (70.83%) compared to the control group (31.76%), suggesting the intervention's potential effectiveness in improving glycemic control among participants.

The intervention group showed notable improvements in diabetes knowledge post-intervention, with intermediate knowledge rising from 13.9% to 43.06% and poor knowledge declining from 45.8% to 26.39%, although good knowledge decreased from 40.3% to 30.56%. The control group exhibited minimal changes, with poor knowledge remaining relatively stable (63.53% to 61.18%) and intermediate knowledge slightly

increasing (35.29% to 37.65%). These findings suggest the intervention effectively enhanced diabetes knowledge in the intervention group compared to the control group, as shown in Table 2.

Table 3 presents the distribution of educational support scores for family members of DM patients across intervention and control groups. The intervention group demonstrated significant improvements post-intervention, with overall educational support mean scores increasing from 61.81 to 90.85. The control group showed a comparatively modest increase, from 55.05 to 64.45. These findings suggest that the intervention was more effective in enhancing understanding and skills related to DM management among the intervention group. Further analysis is warranted to identify factors influencing these outcomes.

Table 4 presents t-test results comparing family educational support behaviors before and after intervention. The intervention group showed significantly greater mean changes across all categories: nutritional regulation, physical exercise, pharmacological therapy, stress management, self-blood sugar test, and overall educational support (all $p \leq .001$). Conversely, the control group demonstrated significant changes only in nutritional regulation ($p = .032$) and physical exercise ($p = .008$), with non-significant results in the remaining categories. These findings indicate the educational intervention effectively enhanced family supportive behaviors compared to the control group.

Table 5 presents the means, standard deviations, and standard errors of family educational support services before and after the intervention across both groups. The intervention group demonstrated substantial improvements across all variables: nutritional regulation (18.57 to 24.50), physical exercise, pharmacological therapy, and overall educational support (61.81 to 90.85). In contrast, the control group showed comparatively modest increases, with educational support rising only from 55.05 to 64.45. These findings suggest that the intervention effectively enhanced educational support and its related components among family members of DM patients.

Table 1. Distribution of respondent characteristics

Respondent characteristics	Intervention group		Group control	
	Total	Presentation	Total	Presentation
Respondent's age				
Not yet productive	0	0	0	0
Productive	66	91.67	80	94.12
non-productive	6	8.33	5	5.88
	72	100%	85	100%
Age of DM patients				
Not yet productive	0	0.00	0	0.00
Productive	56	77.78	60	70.59
non-productive	16	22.22	25	29.41
	72	100%	85	100%
Gender				
Man	13	18.06	21	24.71
Woman	59	81.94	64	75.29
	72	100%	85	100%
Long-time suffering from DM				
≥1 year	29	40.3	16	18.82
1.1-3 years	6	8.3	19	22.35
≤3 years	37	51.4	50	58.82
	72	100%	85	100%
Blood sugar value				
Before intervention (<200)	29	40.3	31	36.47
(>200)	43	59.7	54	63.53
After the intervention (<200)	51	70.83	27	31.76
(>200)	21	29.17	58	68.24

Table 2. Distribution of knowledge before and after intervention in the intervention group and the control group

Knowledge about DM	Intervention group				Control group			
	Total		Total		Total		Total	
	Before	After	Before	After	Before	After	Before	After
Good	29	40.3	22	30.56	1	1.18	1	1.18
Intermediate	10	13.9	31	43.06	30	35.29	32	37.65
Poor	33	45.8	19	26.39	54	63.53	52	61.18

The independent t-test results in Table 6 indicate that before the intervention, no significant differences existed in family educational support between intervention and control groups for exercise ($p = 0.078$), pharmacological therapy ($p = 0.825$), and stress management ($p = 0.373$), except nutrition ($p <$

0.001). After the intervention, all aspects showed significant differences ($p < 0.001$), with the highest increase in overall educational support (mean difference 26.40). These findings demonstrate the effectiveness of the intervention in enhancing family educational support for diabetes mellitus patients, as further illustrated in Figure 1, which compares educational support before and after the intervention.

Table 3. Distribution of mean values, standard deviations, and standard errors of family educational support for family members of DM patients before and after in two groups

Educational supportive sub-variable		Intervention			Control		
		Mean	Std. dev	Std. error	Mean	Std. dev	Std. error
Nutritional regulation	Before	18.57	11.57	1.36	12.66	9.14	.99
	After	24.50	8.75	1.03	15.85	9.71	1.05
Physical exercise	Before	10.22	7.88	.93	8.14	6.82	.74
	After	15.10	7.86	.926	10.89	6.94	.75
Pharmacological therapy	Before	10.88	10.52	1.24	10.55	7.65	.83
	After	17.47	6.67	.79	10.94	7.67	.83
Stress management	Before	10.19	5.75	.68	9.41	5.21	.57
	After	13.90	5.95	.70	10.54	4.98	.54
Self-blood sugar test	Before	11.94	8.62	1.01	14.28	8.11	.88
	After	19.88	8.23	.97	16.22	8.00	.87
Educational support	Before	61.81	34.53	4.07	55.05	32.28	3.50
	After	90.85	22.81	2.69	64.45	29.04	3.15

Table 4. t-test analysis of family educational support for family members of DM patients before and after intervention in both groups

Family educational supportive behavior	Intervention				Control			
	Mean	Std. dev	SE mean	p-value	Mean	Std. dev	SE mean	p-value
Nutritional regulation	-5.93	12.74	1.50	.000	-3.19	13.51	1.47	.032
Physical exercise	-4.88	10.60	1.25	.000	-2.75	9.37	1.02	.008
Pharmacological therapy	-6.60	10.79	1.27	.000	-.389	10.84	1.18	.742
Stress management	-3.71	8.72	1.03	.001	-1.13	7.21	.78	.152
Self-blood sugar test	-7.93	11.01	1.30	.000	-1.94	11.94	1.29	.138
Educational supportive	-29.04	38.07	4.487	.000	-9.40	44.32	4.81	.054

Table 5. Distribution of mean, standard deviation, and standard error of family educational supportive services for family members of DM patients before and after intervention in two groups

Educational supportive sub-variable		Before intervention			After intervention		
		Mean	Std. dev	Std. error	Mean	Std. dev	Std. error
Nutritional regulation	Intervention	18.57	11.57	1.36	24.50	8.75	1.03
	control	12.66	9.14	.99	15.85	9.71	1.05
Physical exercise	Intervention	10.22	7.88	.93	15.10	7.86	.93
	control	8.14	6.82	.74	10.89	6.94	.75
Pharmacological therapy	Intervention	10.88	10.52	1.24	17.47	6.67	.79
	control	10.55	7.65	.83	10.94	7.67	.83
Stress management	Intervention	10.19	5.75	.68	13.90	5.95	.70
	control	9.41	5.21	.57	10.54	4.98	.54
Self-blood sugar test	Intervention	11.94	8.62	1.02	19.88	8.23	.97
	control	14.28	8.11	.88	16.22	7.99	.87
Educational support	Intervention	61.81	34.53	4.07	90.85	22.81	2.69
	control	55.05	32.28	3.50	64.45	29.04	3.15

Table 6. Independent t-test analysis of family educational support for family members of DM patients before intervention in the intervention and control groups

Family educational support	Before			After		
	Mean diff	Standard error difference	p-value	Mean diff	Standard error difference	p-value
Nutritional regulation	5.91	1.65	.000	8.65	1.49	.000
Physical exercise	2.08	1.17	.078	4.20	1.18	.000
Pharmacological therapy	.32	1.45	.825	6.53	1.16	.000
Stress management	.78	.88	.373	3.36	.87	.000
Self-blood sugar test	-2.34	1.34	.082	3.65	1.30	.000
Educational supportive	6.76	5.34	.207	26.40	4.22	.000

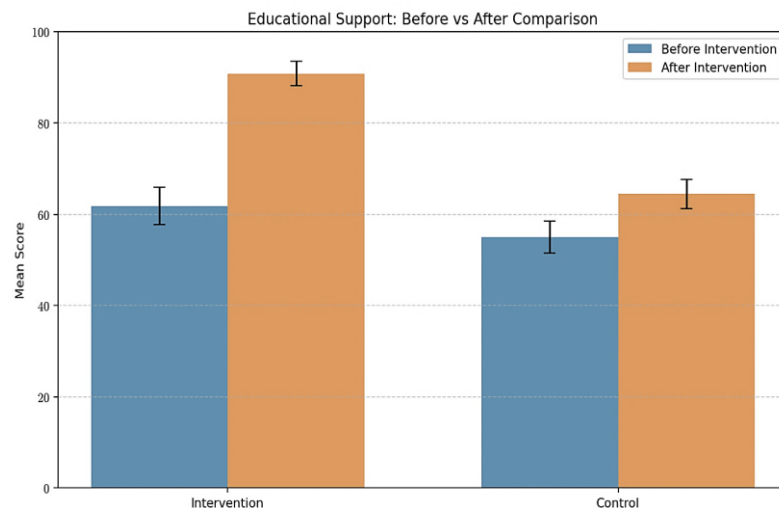


Figure 1. Educational support: before vs. after comparison

The data from Table 2 indicate a significant improvement in diabetic knowledge among participants in the intervention group. Prior to the intervention, 45.8% of the participants demonstrated poor knowledge of diabetes, which decreased to 26.39% following the educational intervention. Conversely, the proportion of participants with intermediate knowledge surged from 13.9% to 43.06% after the intervention, showcasing a substantial shift in understanding. This supports findings by Anggraeni *et al.* [20], who noted that educational programs effectively enhance knowledge levels among type 2 diabetes patients through informational resources and counselling. Similarly, El-Sayed *et al.* [21] affirmed that educational interventions significantly improved both knowledge and self-efficacy, aligning with Varma's findings on enhanced patient knowledge post-intervention sessions.

In the control group, the numbers remained relatively static; the proportion of individuals classified under "good" knowledge consistently remained at 1.18%, indicating a lack of significant improvement. This static situation contrasts starkly with the intervention group's dynamic changes, which concur with the observations reported by Hijriana *et al.* [22], suggesting that educational outreach through structured programs is essential for knowledge enhancement, particularly in the context of diabetes. Furthermore, Rochmah *et al.* [23] corroborate the effectiveness of educational interventions across varied demographics, demonstrating their broad applicability.

In terms of educational support, Table 3 demonstrates notable evidence of improvements in the intervention group pre- and post-intervention. The mean score for nutritional regulation increased from 18.57 to 24.50, and for physical exercise from 10.22 to 15.10, indicating that education has equipped family members to better support diabetic patients in managing their conditions. This comprehensive enhancement of family-supported behaviors is crucial, as effective diabetes management often necessitates individual adherence and the involvement of family systems [24]. Additionally, the findings from Andriyanto *et al.* further emphasize that health education plays a foundational role in motivating individuals towards sustainable lifestyle changes for diabetes management [24]. In contrast, the control group exhibited modest increases in supportive behaviors; for instance, nutritional regulation increased from 12.66 to 15.85. However, the overall changes were not statistically significant compared to the intervention group, where notable improvements were documented across all educational support dimensions [25]. The observations correlate with findings by Hamdi and Jasim [25], which emphasized the need for structured educational interventions to improve knowledge and care behaviors.

The results of the t-test analysis in Table 4 reveal the educational impact on family support measures, particularly in the intervention group. Statistically significant p-values (all < 0.05) across all supportive behaviors emphasize the efficacy of the intervention. The intervention group demonstrated a notable mean improvement of supportive behaviors, reinforcing the importance of family involvement in diabetes self-management. Conversely, the control group exhibited a p-value of 0.054 for educational supportive behaviors, indicating negligible improvement and reinforcing the argument that deliberate educational intervention is essential for fostering effective family support behaviors regarding diabetes management [26]. Sari *et al.* [27] affirm these findings, noting that strong family support significantly correlates with improved self-efficacy and better management practices among diabetes patients.

Moreover, the overall analysis emphasizes that while initial knowledge levels in both groups were inadequate, the structured educational methodologies applied in the intervention group yielded substantial knowledge acquisition and behavioral changes [28]. The importance of addressing both diabetes management knowledge and family support dynamics cannot be overstated, as these factors contribute to improved glycemic control and reduced risks of complications associated with diabetes [29]. The pivotal role of educational programs is underscored by the relationship between knowledge enrichment and behavioral self-management in diabetic care [30]. Future interventions should not only focus on the individual patient but also actively involve family members to create a supportive network that enhances adherence to diabetes management practices.

The mean scores of family educational supportive services encompassing nutritional regulation, physical exercise, pharmacological therapy, stress management, self-blood sugar tests, and overall educational support reveal significant shifts post-intervention, particularly in the intervention group. For nutritional regulation, the mean score increased from 18.57 before intervention to 24.50 afterwards. Contrastingly, the control group's mean score showed only a modest increase from 12.66 to 15.85. This stark difference signifies the potential of well-structured educational interventions to instill healthy dietary practices among family members, aligning with findings from He *et al.* [31], which suggest that personalized nutritional guidance can improve self-management capabilities in patients with diabetes. Zhao *et al.* [32] further support this by indicating that educational interventions effectively promote dietary adherence among DM patients.

The physical exercise dimension likewise exhibits considerable improvement; the intervention group's mean score increased from 10.22 to 15.10, while the control group only depicted a rise from 8.14 to 10.89. The statistical significance of these changes, as evidenced in the independent t-tests (p -value < 0.001), underscores the pivotal role of educational support in promoting physical activity among DM families, a theme echoed by Okafor *et al.* [33] in their exploration of educational programs emphasizing physical activity in diabetic management. Moreover, Chen *et al.* [34] underlined that those educational interventions could significantly enhance participants' physical activity levels.

Examining pharmacological therapy, the intervention group observed a remarkable increase in mean scores from 10.88 to 17.47. In contrast, the control group's slight rise from 10.55 to 10.94 implies a lack of comprehensive educational support in managing pharmacotherapy. This disparity underlines the concept that diabetes self-management education (DSME) is crucial for improving patients' understanding of their medication regimens [35]. Ranjbar *et al.* [36] emphasize that improved self-management behaviors due to educational interventions can enhance adherence to pharmacological therapy.

This improvement extends into stress management, where the intervention group's mean score increased from 10.19 to 13.90, notably outperforming the control group, which only increased from 9.41 to 10.54. The robustness of these educational interventions is critical in alleviating stress levels often associated with diabetes management, as highlighted by Chawla *et al.* [28], who note that structured education programs can provide necessary coping mechanisms for patients dealing with the complexities of their conditions. For self-blood sugar testing, an increase in mean scores from 11.94 to 19.88 for the intervention group demonstrates a significant shift towards proactive self-monitoring practices, a crucial component of effective diabetes management. Conversely, the control group's mean scores increased, but the gain was significantly less, rising from 14.28 to 16.22. Alotaibi *et al.* [37] note that patient empowerment through education enhances self-testing behaviors, thereby improving glycemic control. This observation is complemented by findings from Huang *et al.* [38] affirming that diabetes education positively impacts self-care behaviors.

In the realm of overall educational support, the intervention group saw a pronounced increase from a mean of 61.81 to 90.85, establishing a clear trajectory of improvement compared to the control group's rise from 55.05 to 64.45. This extensive support underscores the importance of comprehensive educational strategies tailored to enhance family involvement in DM management, consistent with studies advocating for family-centered educational approaches in diabetes management [39]. The independent t-test analysis, revealing strong statistical significance ($p < 0.001$), reinforces the argument for systematic educational interventions that encompass various aspects of diabetes care [40].

4. CONCLUSION

The educational intervention significantly improved diabetes knowledge among members of the intervention group, with poor knowledge decreasing from 45.8% to 26.39% post-intervention, while the control group showed no change. The intervention group demonstrated significant improvements across all dimensions of supportive behaviors, including nutrition regulation, physical exercise, and stress management, confirming that structured family education plays a crucial role in diabetes management. The t-test analysis validated these changes, indicating enhanced understanding and family involvement in care.

From a public health perspective, these findings demonstrate that family-based educational interventions can serve as a cost-effective, scalable strategy for reducing diabetes-related complications at the community level, thereby alleviating the burden on primary healthcare systems. By empowering families as active participants in disease management, such programs address social determinants of health and strengthen community resilience against chronic disease. Based on these findings, the following specific policy recommendations are proposed: i) Local health authorities should integrate structured family diabetes education modules into existing primary healthcare curricula at community health centers (*Puskesmas*); ii) Healthcare providers should implement standardized family caregiver training protocols encompassing nutrition counseling, exercise planning, and stress management techniques; and iii) Public health agencies should develop technology-assisted platforms, such as mobile health applications, to sustain family engagement and knowledge retention beyond initial interventions. Future research should evaluate the long-term sustainability of these outcomes and assess cost-effectiveness across diverse sociodemographic populations.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization

M : **M**ethodology

So : **S**oftware

Va : **V**alidation

Fo : **F**ormal analysis

I : **I**nvestigation

R : **R**esources

D : **D**ata Curation

O : Writing - **O**riginal Draft

E : Writing - Review & **E**diting

Vi : **V**isualization

Su : **S**upervision

P : **P**roject administration

Fu : **F**unding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

ETHICAL APPROVAL

This research has received ethical approval from the Mataram Ministry of Health Polytechnic with the number: No. 441/KEPK-TJK/V/2025.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [SF], upon reasonable request.

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